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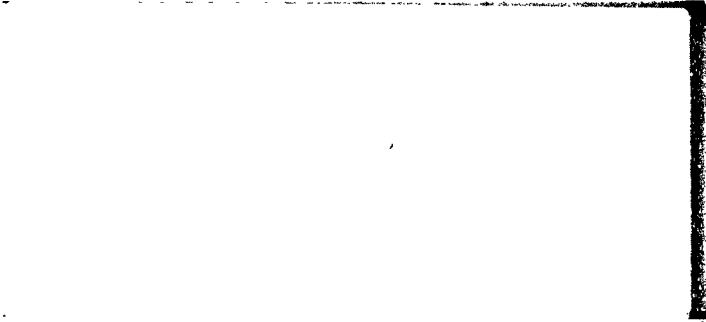
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**Title of Report**

**RADC-TDR-63-46**


**Technical Note No. 8**


**DEVELOPMENT OF AN E-BAND AMPLIFIER**

**Covering the period  
1 October to 31 December 1962**

**PUBLICATION REVIEW**

**This report has been reviewed and is approved.**

**Approved:**   
**EDWARD N. MUNZER**  
Chief, Electronic Warfare Laboratory  
Directorate of Intelligence & Electronic Warfare

**Approved:**   
**ROBERT A. QUINN, JR., Col, USAF**  
Director of Intelligence & Electronic Warfare



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**Technical Note No 8**

**DEVELOPMENT OF AN E-BAND AMPLIFIER**

**Covering the period  
1 October to 31 December 1962**

**E. W. Kinaman**

**Watkins-Johnson Company  
3333 Hillview Avenue  
Palo Alto, California**

**Contractor's Report No. W-J 63-410R32**

**Contract No. AF 30(602)-2422**

**16 January 1963**

**Prepared  
for  
Rome Air Development Center  
Research and Technology Division  
Air Force Systems Command  
United States Air Force  
Griffiss Air Force Base  
New York**

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**DEVELOPMENT OF AN E-BAND AMPLIFIER**

**E. W. Kinaman**

**Watkins-Johnson Company  
3333 Hillview Avenue  
Palo Alto, California**

**Contract No. AF 30(602)-2422  
Project No. 5573  
Task No. 557301**

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United States Air Force  
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## ABSTRACT

Tube No. 5 netted five decibel flange to flange gain at 80 Gc with a circuit badly damaged through abnormal beam interception. The emission of a diode throughout 1450 hours of life test indicates that the service life of 1000 hours should be no problem. Improvements in the cathode, gun, coupling, waveguide, helix, window and filter areas are detailed.

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## 1.0 SCOPE AND PURPOSE

This quarterly report reflects the continuing research and development activities by Watkins-Johnson Company towards producing a low-noise E-band amplifier, having the following design goals.

Frequency range	70-85 Gc
Noise figure	12 db max.
Output power	1 mw min.
Gain	25 db min.
Reverse attenuation	75 db min.
Filter bandwidth	200 Mc (3 db)
Filter tunability	1000 cps min.

Two such amplifiers, with focusing structures and power supplies, will be furnished as contract end-items.

## 1.1 Review of Previous Quarter

### 1.1.1 Tube Development Review

Evaluation of Tube B3, which had 30 db electronic gain, pinpointed the problem of poor waveguide-to-helix coupling. Tube No. 4, a beam tester made at the same time but having no rf circuitry, possessed no emission. The successful focusing (> 99% transmission) noted with B3 canceled the need for further beam testers.

An improved match, featuring a probe extension of the helix, was developed in preparation for tube No. 5. Circuit loss was reduced to a minimum of .27 db/ $\lambda_g$ .

### 1.1.2 Filter Development Review

YIG filter loss was reduced to 1.6 to 2.4 db at an instantaneous 200 Mc bandwidth from 70 to 80 Gc. Initial tests were performed on the magnetic tuning circuit.

## 1.2 Summary of Present Quarter

### 1.2.1 Tube Development

The circuit loss was reduced to values as low as .27 db/ $\lambda_g$  by use of a low temperature "Corning" glaze. Tube No. 5 was constructed with a circuit

of .32 db/ $\lambda_g$  loss and utilized the new probe-type helix-to-waveguide coupling. Results were most encouraging. Overall flange-to-flange gain of five decibels was achieved before abnormal beam interception damaged the circuit. The circuit interception is considered an abnormality. An error in gun construction made it necessary to run several electrodes at incorrect voltages in order to prevent gun arcing. Beam to circuit coupling performed as predicted, and had it not been for the unfortunate arcing, gain would have been adequate for noise figure evaluation.

### 1.2.2 Filter Development

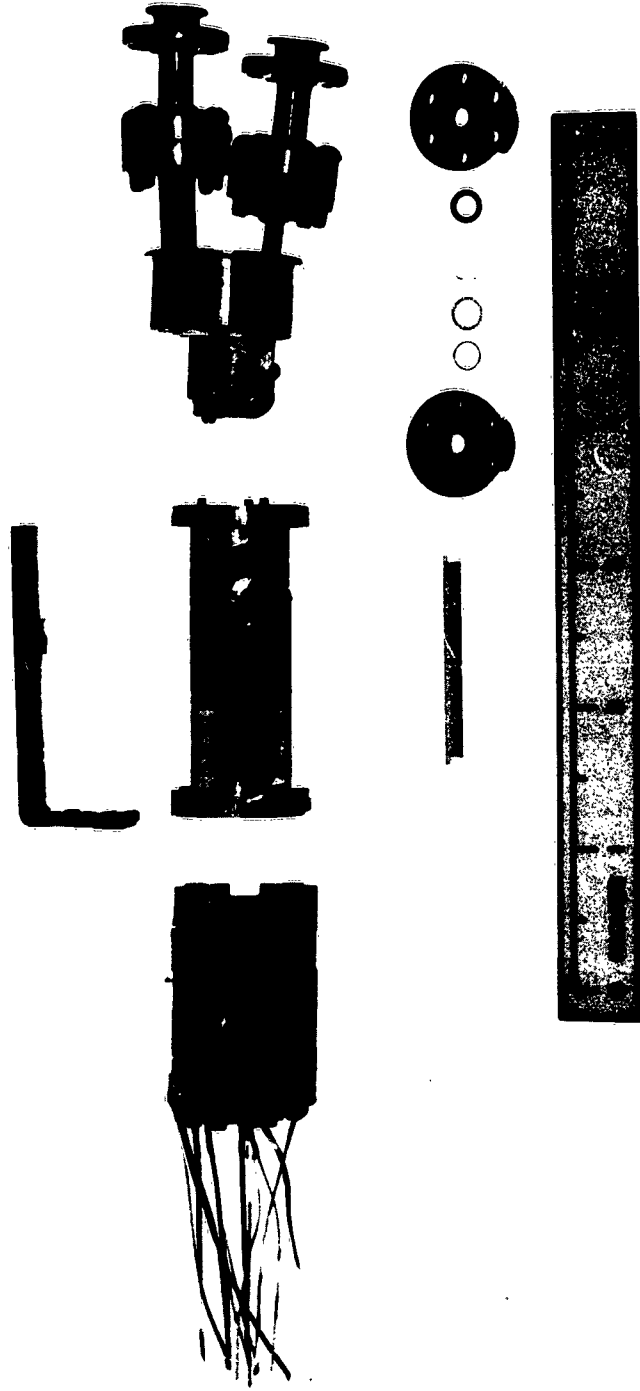
Results of the previous quarter led to the conclusion that improvement of the relative YIG sphere alignment might extend the excellent filter performance through the high end of the band. Accordingly, a filter was assembled wherein both spheres were aligned simultaneously.

## 2.0 TUBE DEVELOPMENT

### 2.1 Fabrication of Tube No. 5

Tube No. 5 utilized a probe-type match (described in Technical Report No. 7). This match provided repeatedly good coupling. Since the match was non-contacting, a new means was required for the helix connection. A strip of "Aquadag" was painted onto the wedge at a point just beyond the circuit center. The width of the strip tapered to .015" at helix contact. DC contact was accomplished with a leaf-spring pushing against the Aquadag on the wedge. The addition of the Aquadag unexpectedly raised the circuit loss by fifteen decibels. This was high enough to act as a circuit sever which reduces the tube gain approximately four decibels.

Fig. 1 provides a view of the subassemblies, some shown in exploded fashion. It is noted that the input waveguide is now separately electroformed (similar to the output waveguide) to assure minimum flange to helix loss. This procedure was adapted as a result of difficulty with the previous method of applying the cover to the waveguide section honed in the block. Another change to be noted is the use of mica compression seal windows. The main advantage here is simple replaceability in the event of a vacuum leak. The previous fused mica to metal window could not be replaced without seriously jeopardizing the entire tube.



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Fig. 1 - The main assemblies and parts shown above are as used in tube No. 5. Note the input waveguide is now fully electroformed to keep its loss controllably low. Compression seal mica windows have replaced the fused type, because of reduced problems in replaceability.

The circuit loss was reduced during the quarter  $\left\{ .37 \text{ to } .27 \text{ db}/\lambda_g \right\}$  by using a low temperature "Corning" glaze. Glazing at  $750^\circ$  produced low circuit loss, because of the absence of cracking in the copper plating. Also the glaze itself possesses lower loss characteristics. The circuit prepared for tube No. 5 was glazed to the wedge in this fashion. Its circuit loss was  $.32 \text{ db}/\lambda_g$  at 80 Gc. The expected tube gain at the design beam current at this circuit loss was ten decibels. The circuit length was adequate for 18 decibels of gain, but the helix contact, incidental waveguide losses coupled with the inactive segment of helix required for the match reduced this about eight decibels. The diode incorporated in tube No. 5 was easily capable of doubling the emission (compared to the design value), so it was concluded that the tube should provide 10 db gain at design current, and 18 db gain at twice design current, which would be adequate for noise figure evaluation.

## 2.2 Evaluation of Tube No. 5

The testing of tube No. 5, was hampered by an internal arc between the leads of anodes 7 and 8 and the cathode cup. The cup, it will be recalled, is several volts negative to prevent side emission from the cathode. The arc prevented proper adjustment of cup voltage except when anodes 4-8 were held 1500 volts below their 2500 volt design value. This forced voltage profile produced a severe beam scallop which resulted in poor transmission even at fields as high as 3500 gauss. During the first hours of test, overall flange-to-flange gain of at least five decibels was recorded at 80 Gc. However, the poor transmission took its toll with gain decreasing with time, apparently from circuit deterioration. Fig. 2 shows the turn-shortening effect of the melted copper plating. This occurred at the output end of the circuit in a region not glazed to the wedge (for satisfying the requirements of the probe match). The input end of the circuit contained no sever, but its plating had vaporized. A section of helix just short of the circuit center similarly contained a group of bridged turns. This helix segment had become detached from the glaze during cold test. Thus, without the thermal conduction of the glazed wedge the plated helix could not dissipate the 0.2 to 0.5 watts of beam power without overheating.

It was deduced from the data showing slope similarity between measured and calculated gain as a function of the cube root of the beam current that beam-to-circuit coupling was as calculated. Thus, in the absence of circuit deterioration gain would have been adequate for noise figure evaluation.

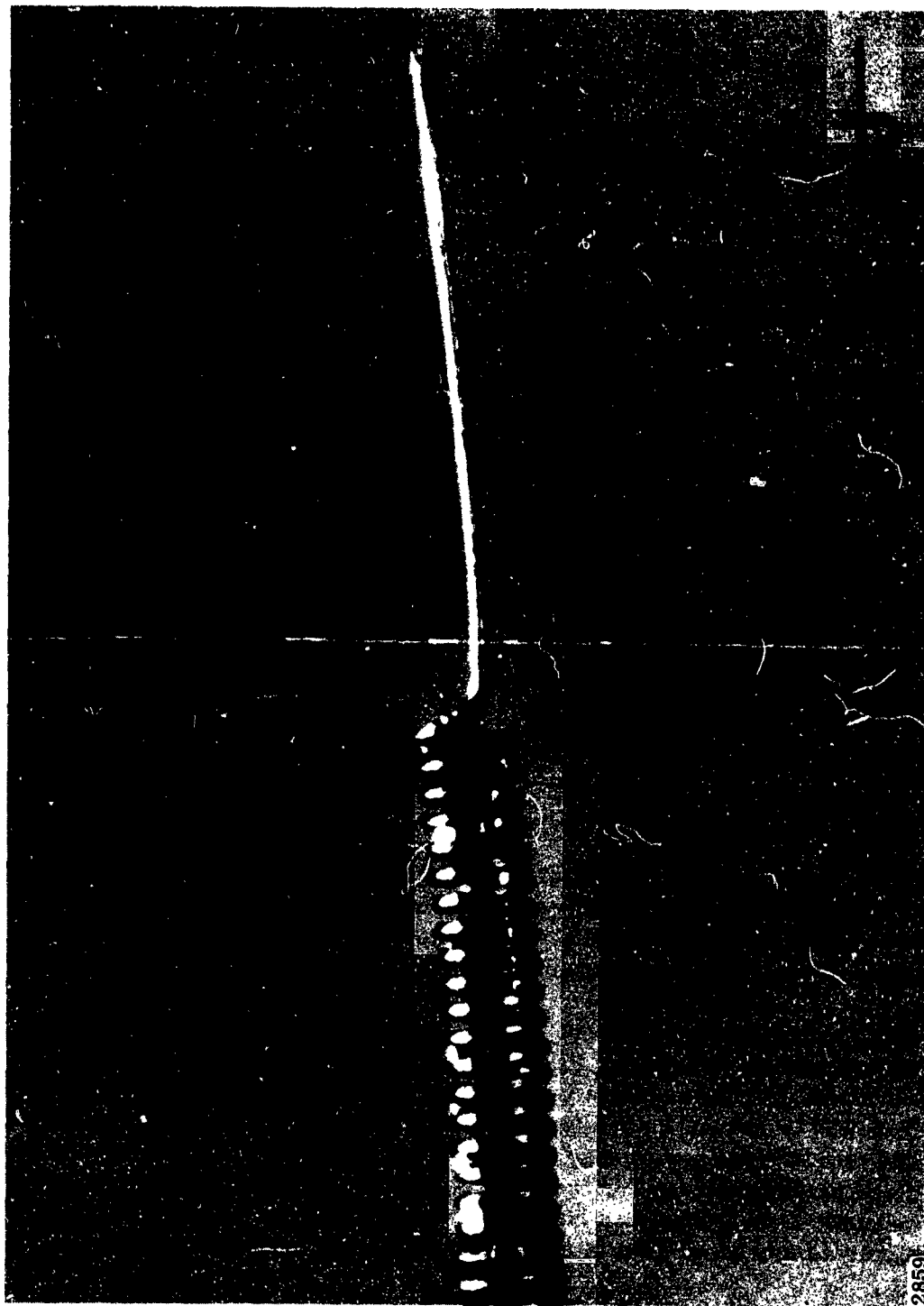


Fig. 2 - Beam interception at the output end of the circuit of Tube No. 5 melted the plating causing many turn-to-turn severs. This occurred in a region where helix overhang prevented removal of heat via the wedge and glaze.



### 2.3 Improvements Scheduled for Tube No. 6

Tube No. 6 will incorporate improvements in protection of the circuit from the destructive power of the beam, and a series of changes directed toward higher tube gain. The wedge has been revised so that more of the helix is glazed to the wedge - perhaps a half-dozen unplated turns will overhang each end. An insulated protective aperture placed between the gun and the helix will prevent any large portion of beam current from striking the helix. The test power supply will be revised to include helix current overload protection, along with provision for cathode-to-anode pulsing. Pulse testing at a low duty cycle can be initially used to determine the general capabilities of the tube, such as the focusing and power handling ability.

Development is near completion on a revision of the probe match wherein the antenna is connected to the waveguide to provide the direct helix contact. This procedure will eliminate the loss of gain associated with the Aquadag-type contact, will be more reliable contact-wise, and will not interfere with measurements of circuit loss. Efforts are underway to increase the available beam current at the same current density by increasing the diameter of the cathode. Changing the diameter from .002" to .0028" would double the available current without materially changing the noise reducing action of the gun.

### 3.0 RELATED DEVELOPMENT

#### 3.1 Diode Life Test

The life test (depicted in Fig. 3 of Technical Report No. 7) was successfully concluded at 1450 hours. The emission was essentially constant for the first 650 hours. During the next 150 hours the cathode and cup currents increased apparently from barium migration onto the cathode side.

This excess emission was cut-off running the cathode cup one volt negative with respect to the cathode for the remainder of the test. During the final 650 hours the anode voltage required for a cathode current of 80  $\mu$ a decreased from 150 to 110 volts. It appears that the cathode activity improved during this period since no increase in cup current was recorded. Also, tests in a magnetic field showed that less than 3.5 percent of the current is cut off by magnetic field intensity as high as 3000 gauss. These latter tests tend to eliminate increased area of emission as a source of the excess current.

Constants  
 $I_{\text{cath}} = 80 \mu\text{a}$   
 $T = 1100^\circ\text{C}$   
 $E_{g3} = 450 \text{ volts}$   
 $E_{g1} = -1 \text{ ''}$

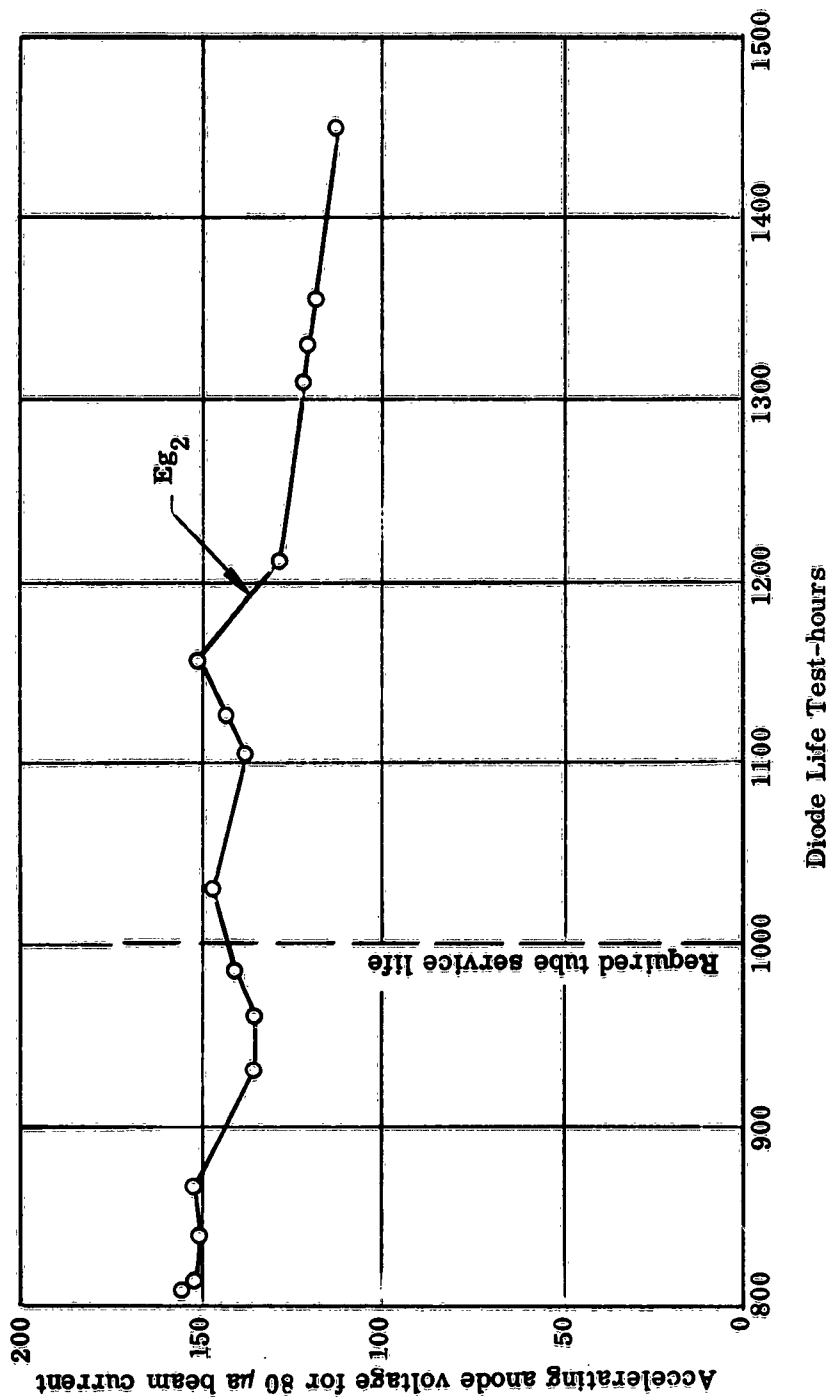
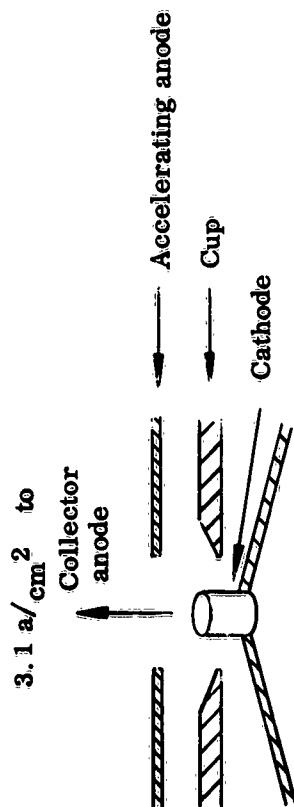


Fig. 3 - The diode life test was successfully completed showing improved emission through 1450 hours. Thus, the basic cathode configuration appears adequate to meet the required 10,000 hours service life.

This life test plus support data from other diodes and tubes indicates that the service life requirement of 1000 hours will be met with the present design. Of course, one diode test of this type cannot guarantee performance of the emitter when used in the tubes. However, based on this limited information, adequate life would not appear to be a problem.

### 3.2 Diode Improvement

Consistent improvement in construction techniques has taken place during the history of the project. Methods are in hand whereby  $3 \text{ a/cm}^2$  of current can be drawn with but 15 volts on the first anode (with negative cup voltage). This improvement reduces the beam impedance transformation required of the gun and similarly provides a better match of the impedance transformation and lens cancelation requirements within the gun. In addition, it opens a whole new field of possibilities wherein basic beam noise can be reduced through the utilization of a low potential drift region, similar to that presently producing ultra low noise tubes at WJ below 4 Gc.

### 3.3 Filter Fabrication

The pressing problems associated with the tube development allowed time but for one further improvement of the YIG filter. As noted in the previous report, sphere misalignment may have been the cause of the poor results above 80 Gc. Accordingly, arrangements were made to simultaneously align .0135" spheres. This should provide the optimum in relative alignment. The assembly is depicted in Fig. 4 where the two spheres are shown housed within polystyrene. The spheres were aligned at 700 gauss with the aid of external vibrations. A drop of benzine was used to soften the polystyrene and mold the assembly in place.

## 4.0 CONCLUSIONS

### 4.1 Tube Development

The attainment of five decibel flange-to-flange gain at 80 Gc was most encouraging, particularly when one considers the poor condition of the circuit. It appears with several small improvements the next tube should provide the first noise figure data.

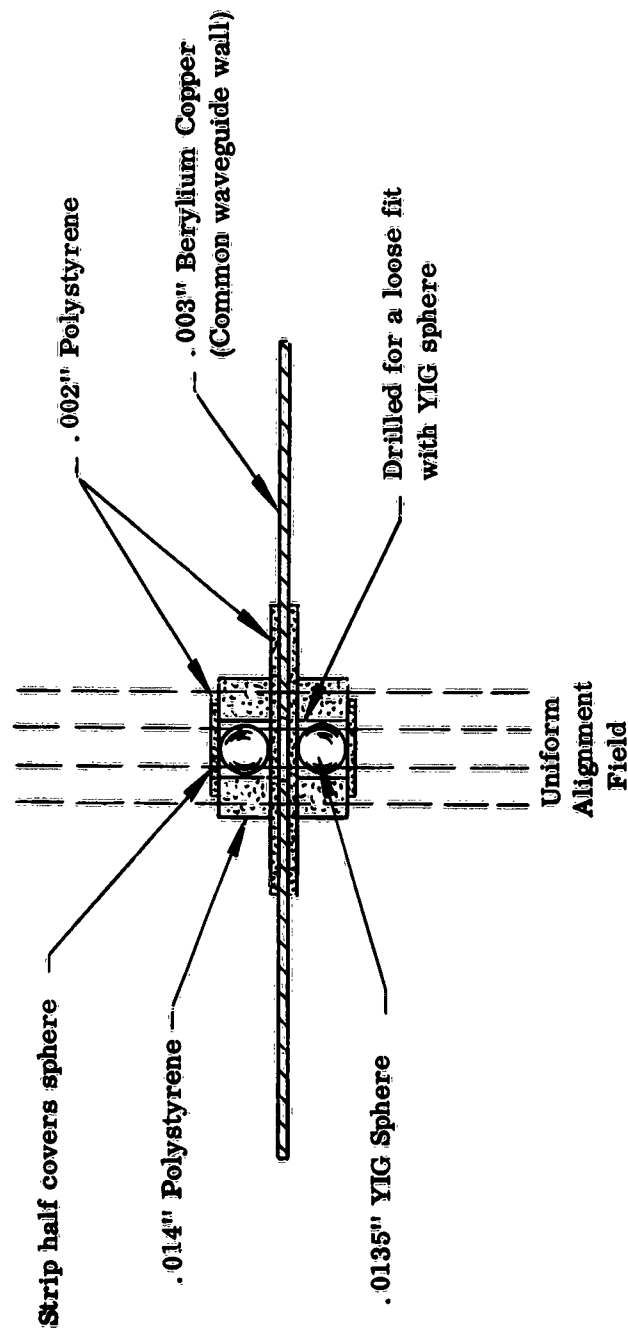


Fig. 4 - The YIG spheres are mounted onto the filters common waveguide wall and simultaneously aligned and molded in a uniform focusing field. This procedure used on the next filter should provide the optimum in sphere alignment coincidence, and perhaps improved higher frequency characteristics of the filter.

The diode life test showing improvement in emission during 1450 hours indicates service life of 1000 hours will not be a problem.

4.2 Filter Development

It would appear that achievement of  $1.5 \pm .5$  db insertion loss at 200 Mc bandwidth is reasonable for the present design.

4.3 Contract Status

A time extension request is still pending.

5.0 WORK PLANNED FOR THE NEXT INTERVAL

5.1 Tube

Build and evaluate two more tubes.

5.2 Filter Plans

Evaluate .0135" YIG filter and other variations as required. Start construction of the sweep solenoid.

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